# Chapter 3—Processes

## 3.1 Background and Overview

The preceding chapters provide the foundations upon which an understanding of Verification, Validation, and Accreditation (VV&A) can be built. The underlying philosophy and the guiding principles associated with VV&A serve as navigational aids in the process of VV&A application and implementation. Chapter 3 builds on this foundation, describing for the use of the VV&A practitioner the fundamental elements associated with a generic VV&A process.

Because the VV&A process shares a symbiotic relationship with the M&S life cycle development process, introductory sections focus on the development process as well as on some of the more commonly used development paradigms. These sections are followed by a description of the generic VV&A process and the application of this process to the High-Level Architecture (HLA) federation development process. Concluding sections discuss VV&A processes as defined by some of the major DoD M&S communities, including those employing legacy simulations, those developing new models and simulations, and those associated with Distributed Interactive Simulation (DIS) or Aggregate-Level Simulation Protocol (ALSP) applications. The relationship of these processes to the generic VV&A process is then explored.

Using the Defense Science Board's definition that "anything short of warfare is a simulation," the spectrum of M&S to be addressed by this document is quite broad and can be represented best as a three-dimensional cube composed of M&S classes, M&S functional areas, and M&S implementations (Figure 3-1).

The dimensions of the M&S cube are defined in the following paragraphs.

### 3.1.1 M&S Classes

All classes of M&S involve computer programs that either replicate military systems or support actual use or testing of military systems. Some M&S involve hardware, actual military equipment, or personnel. Specific classes include the following:

- Constructive—computer simulations, including man-in-the-loop and hardware-in-the-loop M&S
- Virtual—weapon system simulator forces
- Live—instrumented tests and exercises.

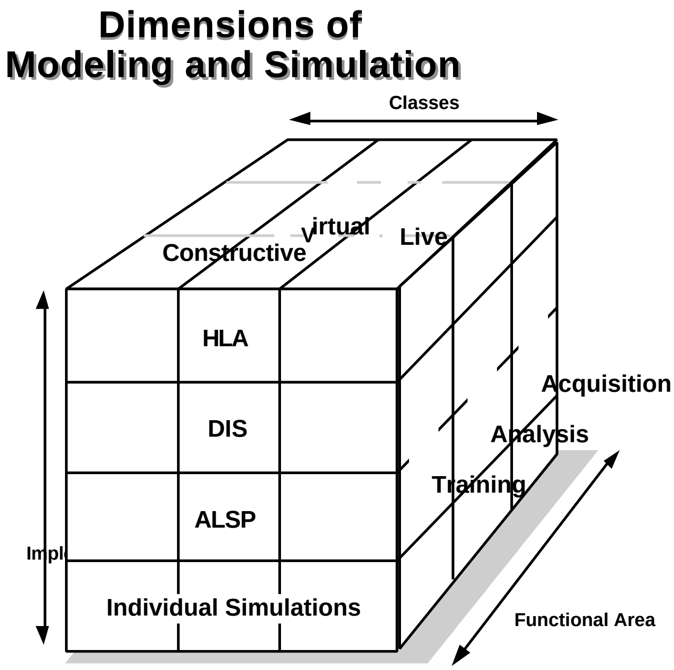



**Figure 3-1. The M&S Cube**

### 3.1.2 M&S Functional Areas

As defined by the DoD Modeling and Simulation Master Plan, there are three functional areas:

- Acquisition
- Analysis
- Training

### 3.1.3 M&S Implementation Types

M&S may be implemented using models and simulations that either stand alone or are brought together in some form of federation. Federations of M&S may be in one place or may be distributed geographically or across multiple platforms. The networking of a computer simulation with a stimulated piece of hardware may be considered a federation, even though the two elements are sitting side-by-side. Alternatively, a federation might involve live players interacting across continents with computer simulations, both constructive and virtual. Current methods of federating M&S include ALSP, DIS, and the HLA, which is designed to provide a common technical framework that promotes and supports interoperability and reuse of M&S across DoD.

## 3.2 Definitions

The definitions for the terms verification, validation, and accreditation, provided in Chapter 1, are repeated here to set the stage for the following discussions of the VV&A process. These definitions reflect the DoD position on VV&A as defined in DoD Directive 5000.59, M&S Management, and DoD Instruction 5000.61, M&S VV&A.

- Verification—The process of determining that a model implementation accurately represents the developer’s conceptual description and specifications

- Validation—The process of determining the manner and degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model

- Accreditation—The official certification that a model or simulation is acceptable for use for a specific purpose

## 3.3 The M&S Life Cycle

### 3.3.1 Process Description

The M&S life cycle underlies all supporting processes such as VV&A, testing, configuration management, quality assurance, and data development. Figure 3-2 depicts the M&S life cycle.

The life cycle is initiated by the definition of a problem that a given user, or application sponsor, needs resolved. Associated with the problem definition is a set of high-level requirements encapsulating the user's objectives. This stage cannot be overemphasized, because all too often, M&S is used without a clear definition of the problem to be solved or the questions to be addressed.

Once the preliminary requirements have been defined, a course of action is selected. The user determines if modeling and simulation is the best approach to obtaining the desired solution. It should be noted that M&S is only one tool available to the user and that other tools may be equally effective or more effective in terms of results, time, and cost.

When M&S is chosen as the methodology to be used, then further definition of M&S type is required. Options include (a) use of an existing (legacy) simulation as is, (b) modification of an existing (legacy) simulation to meet the user's requirements, or (c) development of a new simulation specifically focused on the user's requirements and objectives. Based on this decision, the model or simulation is implemented and applied to the defined problem. Results are integrated, presented to the application sponsor, and archived for future reference. Although Figure 3-2 reflects a linear process, considerable iteration occurs to refine the process as it progresses through the life cycle.

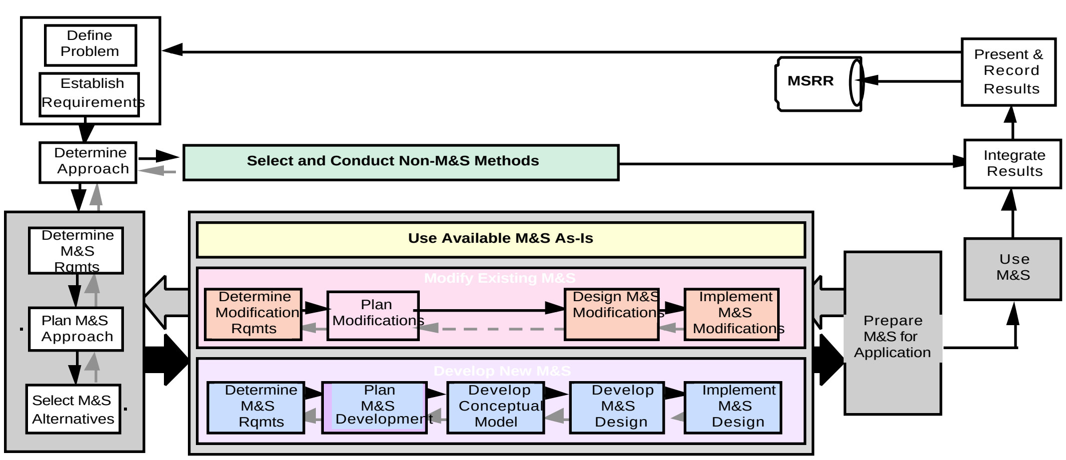



**Figure 3-2. The M&S Life Cycle**

The strategy selected will determine the detailed steps necessary to support implementation and application of the model or simulation. The steps associated with each of the three strategies are as follows.

#### *3.3.1.1 Use Available Model or Simulation As Is*

In this strategy the user elects to implement an existing (legacy) model or simulation without major modification. The decision to use a legacy model or simulation is generally based on either financial limitations or the user's level of comfort with the simulation, based on previous experience or lack of knowledge about alternative simulations. Since the user is ultimately responsible for the results produced by the selected model or simulation, user confidence is a prime motivator in model or simulation selection.

By accepting a legacy model or simulation, the user implicitly accepts its inherent underlying assumptions, limitations, and constraints. Unfortunately, because many legacy models and simulations have not undergone formal VV&A and have no documented conceptual model, the user may not have a clear understanding of the underlying assumptions, limitations, and constraints. Thus, it is most important for the analyst to map the results to the Measures of Effectiveness (MOEs) and Measures of Performance (MOPs) identified as part of the requirements definition stage.

#### *3.3.1.2 Modify an Existing Model or Simulation*

Although the use of a legacy simulation as is does occur, a far more common strategy is the modification of an existing (legacy) model or simulation to meet the user's requirements. This strategy essentially merges the legacy and new development concepts. The implementation steps associated with this strategy parallel those associated with new simulation development with one exception: the lack of formal conceptual model development. Since the foundation of the completed implementation rests on the existing code, an understanding of the original developer's intent or conceptual model is critical. The conceptual model definition includes its underlying assumptions, constraints, and limitations. Although the conceptual model is not formally identified in the modification process diagram (Figure 3-2), it is important that the individuals altering the simulation understand the original developer's intent as well as the current vision for merging the modified code with the existing code. The steps associated with this strategy are as follows (again note that iteration exists at all phases of development).

***3.3.1.2.1 Determine Modification Requirements.*** The user-defined requirements are essential to the development and VV&A efforts. These requirements define the functionality (what the model does) and capability (how well the model does it) that the user requires of the model or simulation. These requirements serve as a framework against which the model or simulation is validated. A set of lower level software and system needs also are derived from the user's requirements. Associated with each requirement is a priority indicating its relative importance to the potential customer's needs. This ranking is a useful decision tool if time or cost constrain the extent of V&V that can be performed. When the model or simulation is to be modified, the higher level requirements focus on the customer's needs, but the lower level requirements address only those parts of the system or software to be changed.

The priorities associated with the user's requirements flow down to the software and system requirements and to the software and system design and implementation. Traceability of requirements through all stages of development helps ensure that the user's needs are being met in the implementation.

Once the developer's vision is established, the low-level requirements of the system and software are defined. Referred to as the Software Requirements Specification, these requirements define the hardware, software, and personnel needed to execute the model or simulation. The specification includes hardware and software for networks and protocols in distributed M&S. Commencement of final model coding before completing the M&S specification is not good practice and can lead to wasteful expenditure of resources and inappropriate code. Preliminary code prepared as part of the rapid prototyping software development approach and selected high-risk code developed in parallel with the specification to ensure feasibility for that element of code are not prohibited.

***3.3.1.2.2 Plan Modifications***. The planning phase of the process defines the roadmap for the development effort. Functions that support planning include the following.

- Definition of MOEs and MOPs
- Definition of scenarios
- Identification of resources and resource availability
- Definition of schedule

- Preliminary development of supporting plans such as federation testing, VV&A, configuration management, and quality assurance. In this instance, plans specify the modifications that are to be made and the approach that will be taken to make them.

***3.3.1.2.3 Design Modifications.*** The outcome of the design phase is the developer's blueprint for the model or simulation. The design process has two primary components: the architectural system design, which addresses the hardware and software architecture, data structures, and interfaces, and the detailed software design, which addresses key elements of the software such as critical algorithms and data issues. Design features emphasize functionality, information flow, ordering of processes, and data accessibility. Any software elements defined in the M&S design are developed in accordance with contemporary standard software development procedures such as the ANSI/IEEE series or DoD standards. During the M&S design phase, the development plan will be updated to reflect more accurately management issues (tasks, schedule, and resources) to be addressed and analysis actions (scope, limitations, constraints, methodology, sources of data, testing, and acceptability criteria) to be taken. In this instance, the design will focus on the required modifications. Documentation that supports the original M&S design is extremely helpful to any modification effort. If the documentation does not exist, parts of it that are relevant to the specific application may need to be redeveloped to support the modification.

***3.3.1.2.4 Implement Modifications***. M&S implementation is the combination of computer code, processes, equipment, networks, operators, and personnel that compose the model or simulation. By maintaining connections among the requirements, the design, and the implementation, it is possible to identify the elements of the design or implementation that are affected by a given requirement. As requirements shift, these mappings help simplify the modification process.

***3.3.1.2.5 Prepare for Application.*** The model or simulation is applied to a specific problem using resources developed during the design, construction, and test phase to satisfy objectives established during the planning and requirements phase. This phase does not begin until V&V has been completed.

***3.3.1.2.6 Use Model or Simulation and Integrate Results.*** Once the model or simulation has been accredited, it is implemented. Output data are collected and results are analyzed, after action reviews are conducted and the accreditation report is prepared.

***3.3.1.2.7 Present and Record Results.*** Results are forwarded to the decision maker according to established reporting requirements.

#### *3.3.1.3 Develop a New Model or Simulation*

In this strategy the user elects to build the model or simulation from scratch and defines specific requirements to which the model or simulation will be built. This approach allows the most effective integration of VV&A into the development process, as VV&A can be incorporated in the earliest stages and tightly coupled with each succeeding phase of development. The steps associated with this strategy mirror those associated with the modification of an existing simulation (see Section 3.3.1.2), with the addition of the definition of a formal conceptual model.

The conceptual model serves as a bridge between the defined requirements and the M&S design, providing the developer's interpretation of the requirements to which the model or simulation will be built. The conceptual model is a statement of assumptions, algorithms, and architecture that relates the elements of the model to one another (and to other models or simulations in federated simulation environments) for the model's or simulation's intended applications. The conceptual model also addresses the availability of appropriate, certified input data for the new model or simulation. The approach to developing the conceptual model should be iterative, allowing communication between the developer and the intended user. Failure to develop an adequate conceptual model before final design and implementation has been a major cause of past M&S inadequacies.

### 3.3.2 M&S Development Paradigms

The M&S life cycle defined in Section 3.3.1 is generic in nature and can be implemented in many different ways, including the waterfall, spiral, iterative, evolutionary, fountain, rapid application development, and model-test-model methods. Availability of resources, especially time, must be considered when selecting a development methodology or paradigm. When the time schedule is tight or compressed, the best method is the one that is familiar and simple to use. Newer, unfamiliar methods can be selected when learning time will not have a significant schedule impact.

Some of these approaches are discussed in the following paragraphs.

#### *3.3.2.1 Waterfall Development Cycle*

The Waterfall Development Cycle (Figure 3-3) is the more traditional development process for M&S. It is a structured, step-by-step functional development process that closes out each phase before starting the next. This structured process also facilitates In-Process Reviews (IPR), Preliminary Design Reviews (PDR), and Critical Design Reviews (CDR) at the end of each step in the development. This structured review correlates the intent of the developers and the desire of the user. Before the next step proceeds, differences are resolved and approval by the cognizant authority obtained.

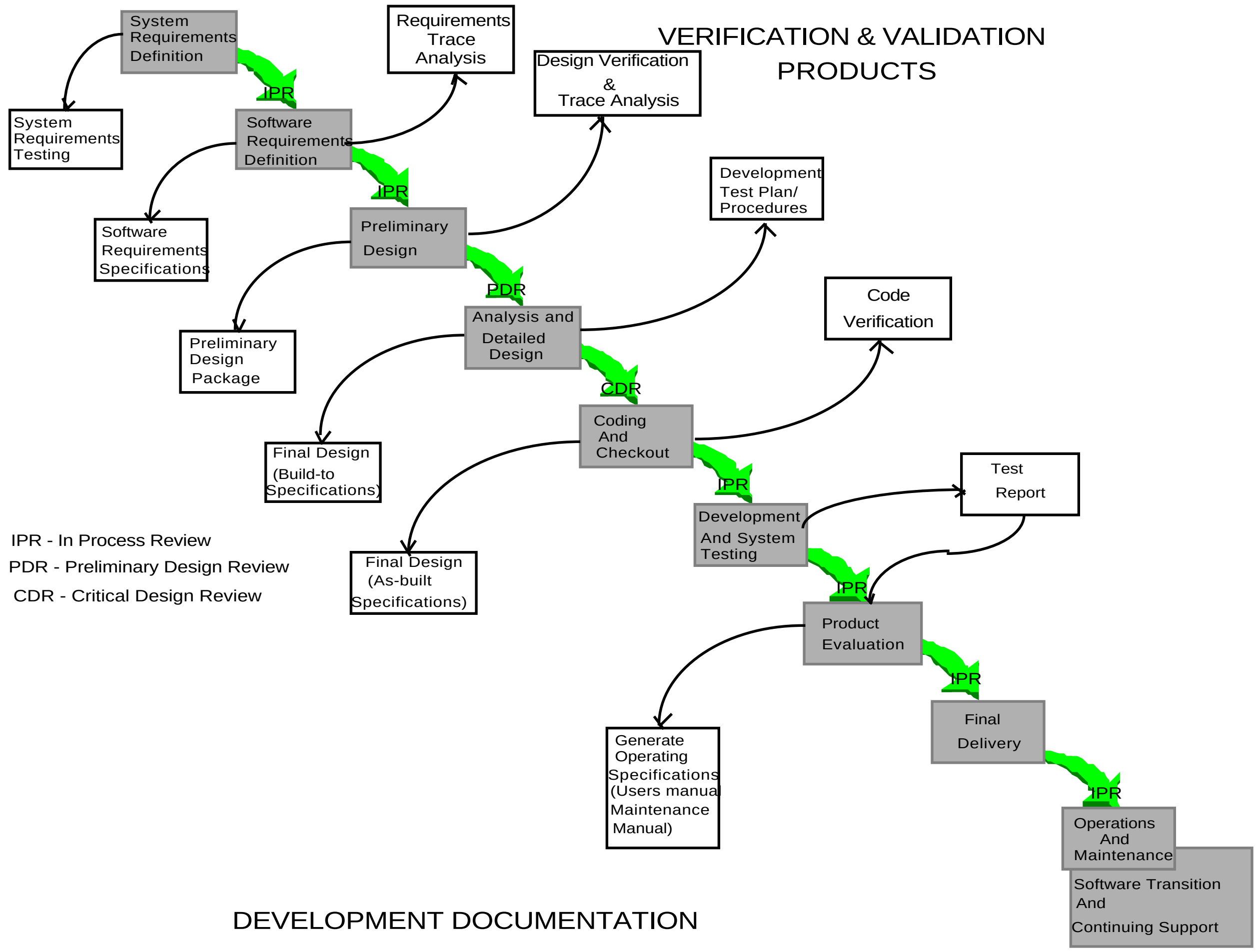



**Figure 3-3. The Waterfall Development Cycle**

Other characteristics of this process include the following:

- It encourages specification before building the system: requirements are defined before designing.

- It assesses the interaction of components before they are built: design before implementation.
- It enables the tracking of progress more accurately to uncover possible slippages early.
- It facilitates the generation of a series of documents that can be utilized later to test and maintain the system.

### 3.3.2.2 Spiral Development Cycle

The spiral software development cycle, shown in Figure 3-4, is an evolutionary prototyping methodology that is extremely useful when requirements are not well-defined.

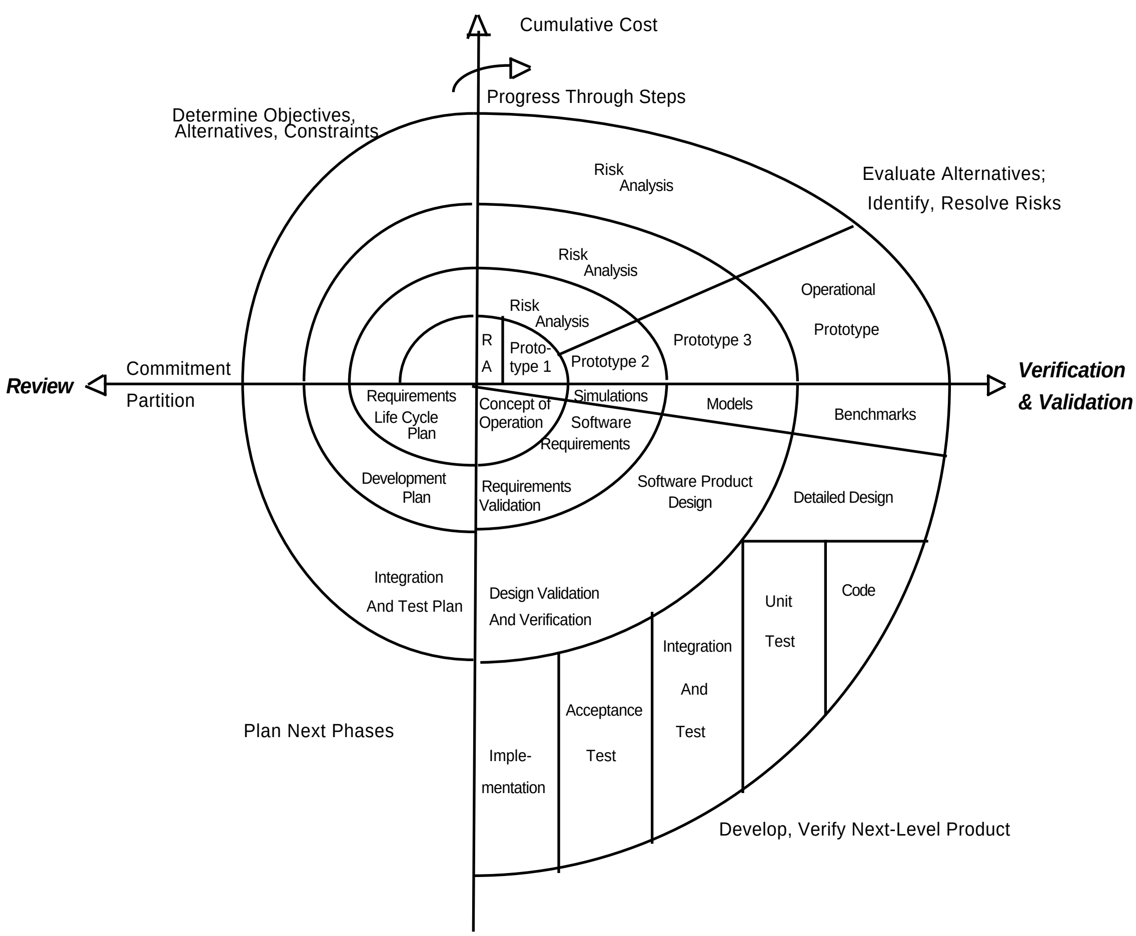


**Figure 3-4. The Spiral Development Cycle**

The spiral methodology employs an iterative process, with the first iteration beginning at the center of the spiral and working outward. A partial implementation of the system that meets the known or perceived requirements is constructed. The prototype is then employed and evaluated at the same time by its intended user in order to understand the full requirements better. The spiral model has four major activities:

- Planning—determining objectives, alternatives, and constraints of the development effort
- Risk analysis—analysis of the alternative approaches that could be employed and identification of risk
- Engineering—design and implementation of the model or simulation
- Customer evaluation—assessment of the resulting product

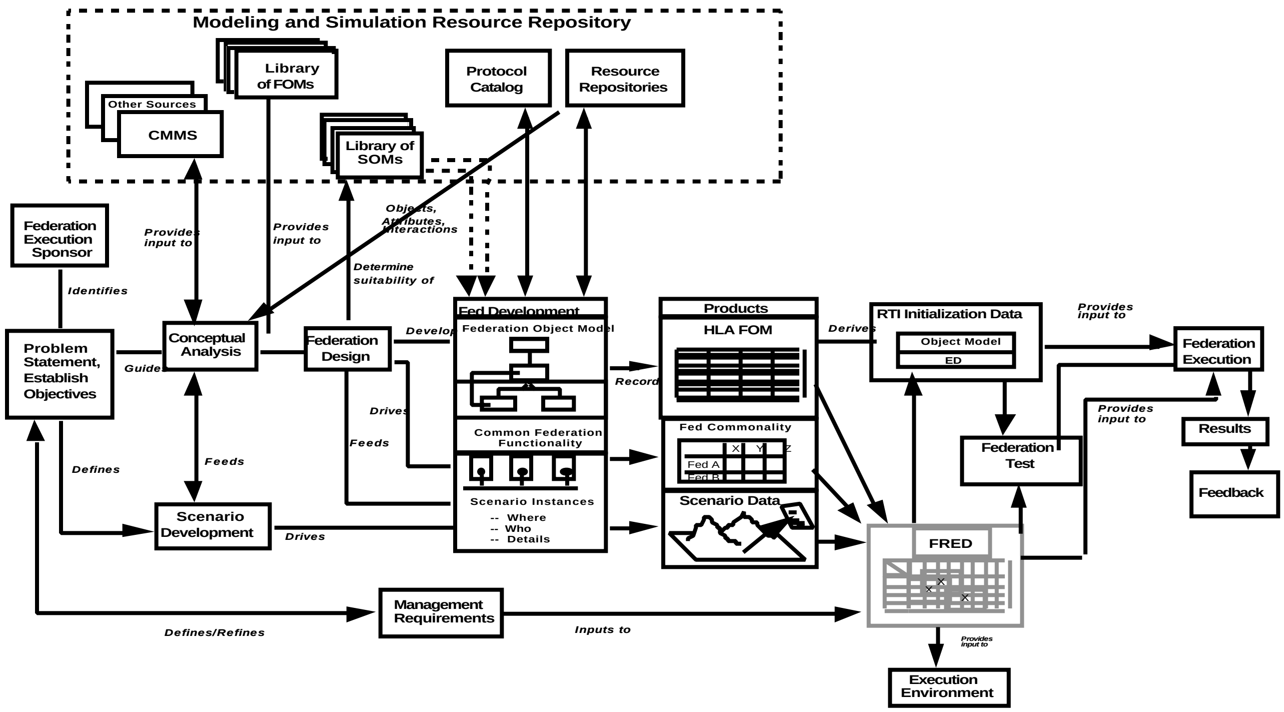
As defined in the spiral development process, *evolutionary* prototyping implies that requirements are not all known at the beginning and experiments with the operational system are needed to create a more useful product. *Incremental* development implies that most of the requirements are understood initially and are implemented in subsets of increasing capability. With this method, the developer is more apt to start implementation with those aspects of the system that are best understood and thus build on strengths.

### *3.3.2.3 High-Level Architecture Federation Development Process*

As has been previously noted, the development of DoD's Common Technical Framework significantly affects the way in which M&S is used in DoD. The HLA is the central focus of the Common Technical Framework and offers a unique solution to building models, simulations, and federations by promoting interoperability and reuse. The emphasis is on providing those elements of federations that are common to all uses so they need not be rebuilt each time. These features include a run time infrastructure, rules, interface specifications, and object model templates. Technical documents are available that explain the details of these features; however, the following description of the HLA, illustrated in Figure 3-5, is intended to be as easy to understand as the material will allow!

The HLA can be applied to all three functional areas and can use all three M&S classes illustrated in Figure 3-1. HLA applications use federations of models and simulations, known as federates, which have been grouped together to solve a specific problem.

As with any application of M&S, the first step is for the application sponsor to define the problem statement and objectives. This step corresponds to the “Define Problem” and “Establish Requirements” boxes in the upper left corner of the M&S life-cycle diagram (Figure 3-2). The approach for an HLA application presumes the use of M&S to solve the problem that has been identified by the sponsor. The problem definition is used to generate specific M&S requirements, the approach that will be taken, and the selection of the model suite that will be used.




## Figure 3-5. The HLA Federation Development Process

**NOTE: Federation Object Models (FOMs), Simulation Object Models (SOMs), and Federation Required Execution Details (FRED) are discussed below.**

The federation developers use high-level requirements to define a scenario in which the given problem is studied and solved. The scenario includes the major entities represented in the federation, a conceptual description of their capabilities, behavior, and interactions over time, and a specification of environmental factors and conditions. Scenario development is one of the key M&S requirements described in Figure 3-2.

The next step is a conceptual analysis that decomposes (breaks down) the scenario into conceptual-level components, which are usually expressed as objects and interactions. This step is part of the planning stage and precedes the development of a conceptual model. The result of this analysis is a conceptual model that provides a framework for the federation's design.

Conceptual analysis draws upon the Conceptual Models of the Mission Space (CMMS), which is the second of the three legs of the Common Technical Framework (the HLA and Data are the other two). CMMS are first abstractions of the real world; they capture basic information about entities, their actions, and interactions from a simulation-neutral viewpoint. CMMS content is validated by authoritative data sources from the warfighter community. The CMMS is based on the Uniform Joint Task List (UJTL).

The next step is the design of the federation itself. Although it would seem that this step would correspond directly to the "Develop M&S Design" step in the generic M&S development process, it also includes part of the conceptual modeling phase. The primary emphasis is the identification of the principal members of the federation and negotiation among these federates as to how the federation will be developed. Other tasks include defining the objects, attributes, and interactions that will be exchanged among federates; outlining specific responsibilities of each federate; and reviewing existing Federation Object Models (FOMs) and Simulation Object Models (SOMs) that may be re-used in the federation under development.

SOMs are descriptions of those key features, including objects, behaviors, and relationships, that an individual simulation brings to the federation negotiation table. The FOM is the superset of the SOMs that have been selected for use in a given federation. The FOM incorporates the definition of all the objects, interactions, state transitions, and communication flows that will occur within the federation. The FOM is the federation blueprint, an agreement between the federates concerning what will be built.

FOMs and SOMs are stored in the Modeling and Simulation Resource Repository (MSRR), which also includes data, metadata, models, simulations, and VV&A histories. In addition to FOMs and SOMs, the federation design also calls upon protocol catalogs that contain standard data definitions and formats. Protocol catalogs are, likewise, contained in the MSRR.

Simultaneous to federation design and part of the generic “Develop M&S Design” step is the development of FRED, the Federation Required Execution Details. In a nutshell, FRED is how the FOM works internally. It includes networking requirements, the physical connections that make the federation work, and the platforms and nodes of which the federation is composed.

The generic “Implement the M&S Design” step parallels the next step of federation development. In this step, the FOM, common simulation functionality, and data needed to support the federation scenario are developed collaboratively among the federates. Common simulation functionality comprises those tasks that all the federates need to do and can use the same thing to do it, such as a common clock, a common data base, or shared common algorithms that ensure a fair fight when the simulations run together.

Federation development also includes confirmation of each federate’s responsibilities to each other. Relationships between objects are defined. Negotiations among the federates continue as to what attributes (planes fly) and level of functionality (how high) must be developed, incorporated, and maintained by the federates. The federates also must agree on object interaction protocols (how do tanks act around ground troops?) and common representations (which terrain data base will be used?).

The products from the federation development stage are the FOM, definition of common simulation functionality, and identification of scenario details.

Completing development is the Run Time Infrastructure, or RTI. The RTI is simply the physical implementation of the three big pieces of any HLA application: the rules, the interface specifications, and the object model template. These detailed documents were mentioned in the first paragraph of this section; they are available from the DMSO Web page where you probably found this guide!

The RTI needs data from the FOM and FRED to start up. Beginning as a clean slate, the RTI first takes “object model data” from the FOM. These are simply the tables of data that will be exchanged among the federates. The other data taken from FRED are the execution details of how the federation runs, how information is passed, and who gets what messages. RTI initialization is equivalent to the “Prepare M&S for Application” box in the generic process.

The federation is now ready to be tested. There are two kinds of tests, HLA compliance testing and federation functional testing. The first asks if information gets passed correctly within the federation when it is connected to the RTI. The second tests the logical interactions between the federates, checking that the information that is passed makes sense.

Finally, the federation is run and the results are analyzed to obtain a solution to the problem that was specified at the very beginning. This step is the point of the process, to answer the questions posed and provide the decision maker with a solution.

### *3.3.2.4 Distributed Interactive Simulation Exercise Development Process*

DIS is a government and industry initiative to define an infrastructure for linking simulations of various types at multiple locations to create a realistic, complex, virtual environment for the simulation of interactive activities. (See Figure 3-11.) This infrastructure brings together platforms from the Military Services and systems built by various vendors using different technologies for different purposes and permits them to interoperate. DIS exercises support a mixture of virtual entities with computer-controlled behavior (computer-generated forces), virtual entities with live operators (human-in-the-loop simulators), live entities (operational platforms, test and evaluation systems), and constructive entities (automated simulations, wargaming). DIS draws heavily on experience derived from the Simulator Networking (SIMNET) program developed by the Defense Advance Research Projects Agency (DARPA), adopting many of SIMNET's basic concepts and heeding lessons learned from those experiences.

The DIS exercise development process illustrated in Figure 3-6 consists of the five major activities or phases summarized in the following paragraphs.

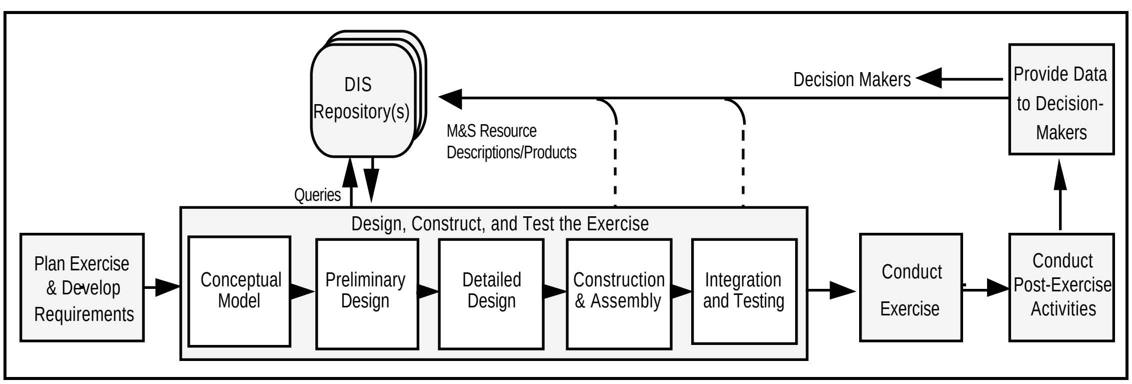



**Figure 3-6. The DIS Exercise Management and Feedback Life Cycle**

***3.3.2.4.1 Plan Exercise and Develop Requirements***. This phase includes a number of functions that support proper planning:

- Determining MOEs, MOPs, and exit criteria applicable to the exercise
- Developing support plans (e.g., VV&A plan, VV&C plan)
- Defining exercise environment (e.g., weather, climate, electromagnetic conditions, oceanographic features)
- Determining the mix of simulation forces among live, virtual, and constructive categories
- Determining simulation resources available
- Determining technical and exercise support personnel required
- Developing requirements and network interface specifications.

These same functions support the development of VV&A plans.

***3.3.2.4.2 Design, Construct, and Test the Exercise***. In this phase, the exercise is developed to meet the requirements specified during the planning phase. This phase consists of five steps:

- Conceptual model—The conceptual model represents the exercise architect's understanding of the exercise requirements and purpose. It serves as the foundation for the design and development of the exercise configuration.
- Preliminary design—The conceptual model is translated into a high-level design of the exercise. An architecture is created to show the participating components, their interfaces, behavior, and control structure.
- Detailed design—The design model and architecture generated in the previous step are elaborated to support the complete definition of all required functions, data flow, and behavior, including communication data-rate requirements and data-latency limitation requirements.

- Construction and assembly—The existing DIS components are assembled and new components are developed.

- Integration and testing—This step is usually performed as an incremental process, starting with a minimum number of components and connectivity and building until operational status is achieved. Testing occurs to determine if requirements and performance criteria are met.

Verification and validation activities are conducted during and following each step and results must be accepted by the exercise manager before proceeding. Section 3.4.4.3 provides additional information on the DIS VV&A process.

***3.3.2.4.3 Conduct the Exercise***. The exercise is conducted using resources developed during the design, construction, and test phase to satisfy objectives established during the planning phase. This phase does not begin until exercise verification and validation has been completed and exercise configuration has been accredited.

***3.3.2.4.4 Conduct the Post-Exercise Activity***. This activity includes the collection and processing of output data, analysis of results, after action review (AAR), and preparation of exercise documentation.

***3.3.2.4.5 Provide Results to Decision Makers.*** Exercise results are reported to the decision makers according to the reporting requirements of the exercise.

### *3.3.2.5 Aggregate-Level Simulation Protocol Exercise Development Process*

The Joint Training Confederation (JTC) is an integrated network of distributed interoperable simulations used by the Commanders in Chief (CINCs) and subordinate commands in joint training exercises to identify wartime capability and readiness issues. The ALSP Program supports the JTC by providing the simulation architecture, protocols, and software that integrate the individual Service campaign-level simulations into a single environment. The JTC is revised annually to reflect key aspects of air, land, and maritime warfare operations and training requirements identified by the CINCs.

The JTC development cycle begins with the existing JTC capabilities, simulations, and test tools. Feedback from the CINCs and Services identifies deficiencies and recommends functional improvements to the participating simulations or changes in the ALSP architecture to increase training realism or to improve efficiency.

## 3.4 The VV&A Process in the M&S Life Cycle

The VV&A process is an integral part of the M&S life cycle (Figure 3-7). The primary purpose of the VV&A effort is to establish the credibility of the model or simulation. Much like building a body of evidence in a court case, the VV&A agent derives and accumulates data that will support a judgment or accreditation decision regarding the acceptability of the model or simulation for a given application.

A secondary function of VV&A is to support risk mitigation. By identifying potential errors and problems early in the development process, verification and validation efforts aid in the development of an accurate and cost-effective model or simulation.

### 3.4.1 Process Description

The following paragraphs describe the seven steps of the VV&A process, which are grouped in the box entitled “Conduct Verification, Validation, and Accreditation” in the lower right corner of Figure 3-7.

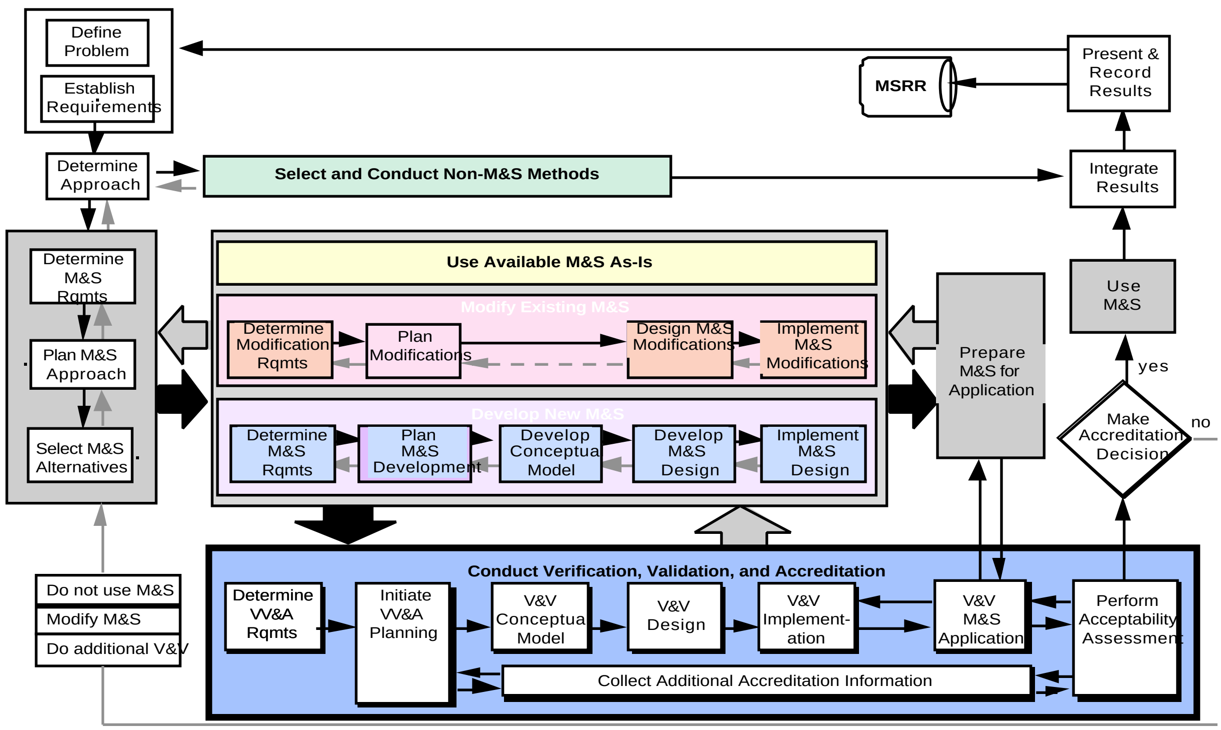



**Figure 3-7 The Generic VV&A Process**

### 3.4.1.1 Determine VV&A Requirements

Once the method for implementing a model or simulation has been chosen (legacy, modify, or build new), requirements must be defined by which the success of the VV&A effort will be judged. VV&A requirements include determining the level of effort for the VV&A process and techniques that will be used, as well as logistic factors such as the identification of the V&V agent, number of workhours required, hardware and software needs, and an estimate of overall VV&A costs.

### 3.4.1.2 Initiate VV&A Planning

The focus of each plan (see Chapter 6 for more information on plans) is to identify the tasks required in a manner that matches and complements the M&S plan, requirements, resources, and timelines. Each plan is adapted to address the requirements and constraints of the M&S application and covers critical issues, while allowing flexibility for adjustment and refinement.

Formal guidance and requirements are collected and reviewed to determine the constraints under which the model V&V; Verification, Validation, and Certification (VV&C); VV&C, and accreditation efforts will operate and appropriate evaluation techniques and measures are identified. Necessary tools and resources are further identified and specific activities scheduled. Initially, the plans are developed as drafts or working documents that evolve as the application takes shape. When new information is available or changes occur, the plans are reviewed and updated as appropriate.

#### *3.4.1.3 V&V the Conceptual Model*

In Chapter 1 “conceptual model verification” was loosely defined as “Did I build the thing right?” and “conceptual model validation” as “Did I build the right thing?” Verification satisfies the functional requirements, validation the fidelity requirements. Both the conceptual model and its V&V must be documented. The documentation explains why (or why not) the assumptions, algorithms, modeling concepts, anticipated data availability, and architecture of the conceptual model are expected to provide an acceptable representation of the subject modeled for intended application of the model or simulation. Any interactions expected with other models or simulations (as in a federation) must be taken into account. Conceptual model verification and validation should occur before further M&S development to avoid the potential pitfall of inaccurately representing the system and not meeting the proposed requirements. Errors caught at this early stage of development are easier and less expensive to fix.

#### *3.4.1.4 V&V the Design*

As it is constructed, the M&S design is verified against the conceptual model to ensure that it accurately reflects the validated concept and associated requirements. The M&S design has an associated V&V plan, which addresses management (tasks, schedule, and resources) and analysis (scope, limitations, constraints, methodology, sources of data, testing, and acceptability criteria) actions for V&V during M&S development. In some cases, an Independent Verification and Validation ( IV&V) plan may be appropriate. (See Chapter 1 for a discussion of the relevance of IV&V.)

#### *3.4.1.5 V&V the Implementation*

Once the implementation of the design is completed in code, the results of the model or simulation are formally (i.e., documented) reviewed. Responses of the model or simulation are compared against known or expected behavior from the subject it represents to ascertain that the M&S responses are sufficiently accurate for the intended use. The developer of a model with stochastic processes is expected to provide guidance regarding the number of iterations required for statistically significant results.

#### *3.4.1.6 V&V the Application*

Once the model or simulation is ready to be run, the application context needs to be verified and validated. This includes such housekeeping tasks as ensuring that the appropriate platforms are being used and that operators and humans-in-the-loop are properly trained.

#### *3.4.1.7 Perform Acceptability Assessment*

This step reviews the information collected during the V&V assessment of the model or simulation for use in the intended application. This is the final step before deciding to accredit and use the model or simulation for the given purpose. Documentation that supports the acceptability assessment includes a comparison of the application M&S requirements to the simulation’s capabilities and limitations; model or simulation development and use history; model or simulation operating requirements and cost; implications of the model’s or simulation’s limitations and constraints for use in this application; and recommendations for changes to allow the model or simulation to be used for the application or to reduce application risk. (Chapter 6 contains additional guidance for preparing the *Acceptability Assessment Report*.)

### 3.4.2 A Note on Tailoring

A VV&A effort must be cost-effective, responsive, and sufficient to succeed. To maintain a balance between application requirements and real-world constraints, the VV&A process should be tailored to fit the purpose of the application and the type(s) of simulation(s) involved. Tailoring, the selection of verification and validation techniques (see Chapter 4) based on requirements and resource availability, is done as part of the

VV&A planning process to determine the most appropriate and cost-effective ways to address the application requirements and acceptability criteria.

### 3.4.3 VV&A As Applied to High-Level Architecture

The HLA federation development life cycle shown in Figure 3-8 has been modified to reflect the interaction with VV&A. The HLA Baseline Definition document includes a section that discusses many of the VV&A aspects discussed in the following paragraphs.

As discussed earlier, the initial tasks of stating the problem and establishing requirements are combined in the HLA process diagram (Figure 3-5). Determining VV&A requirements naturally are included in this process.

VV&A planning is initiated in the Conceptual Analysis stage of HLA federation development. It uses the products of Scenario Development to determine the degree of V&V that is required to ensure the accurate representation of major entities and their interactions. Environmental conditions also must be verified and validated to ensure consistency with conceptual intent and real-world accuracy at a level that is appropriate to the intended use of the model.

V&V of the conceptual model includes three major portions of the federation development process (speckled overlay). Conceptual Analysis, Federation Design, and portions of Federation Development all involve Conceptual Model V&V. The definition of objects and interactions which results from the Conceptual Analysis stage requires V&V to ensure that these objects and interactions are accurately represented.

Identification of the federates and their individual responsibilities is one focus of Federation Design. Here, V&V plays a major role in checking the V&V history of the federates and determining the additional V&V that is required to make those simulations credible for the purposes of the federation. Emphasis is placed on the realistic portrayal of federate capabilities in carrying out proposed responsibilities within the federation.

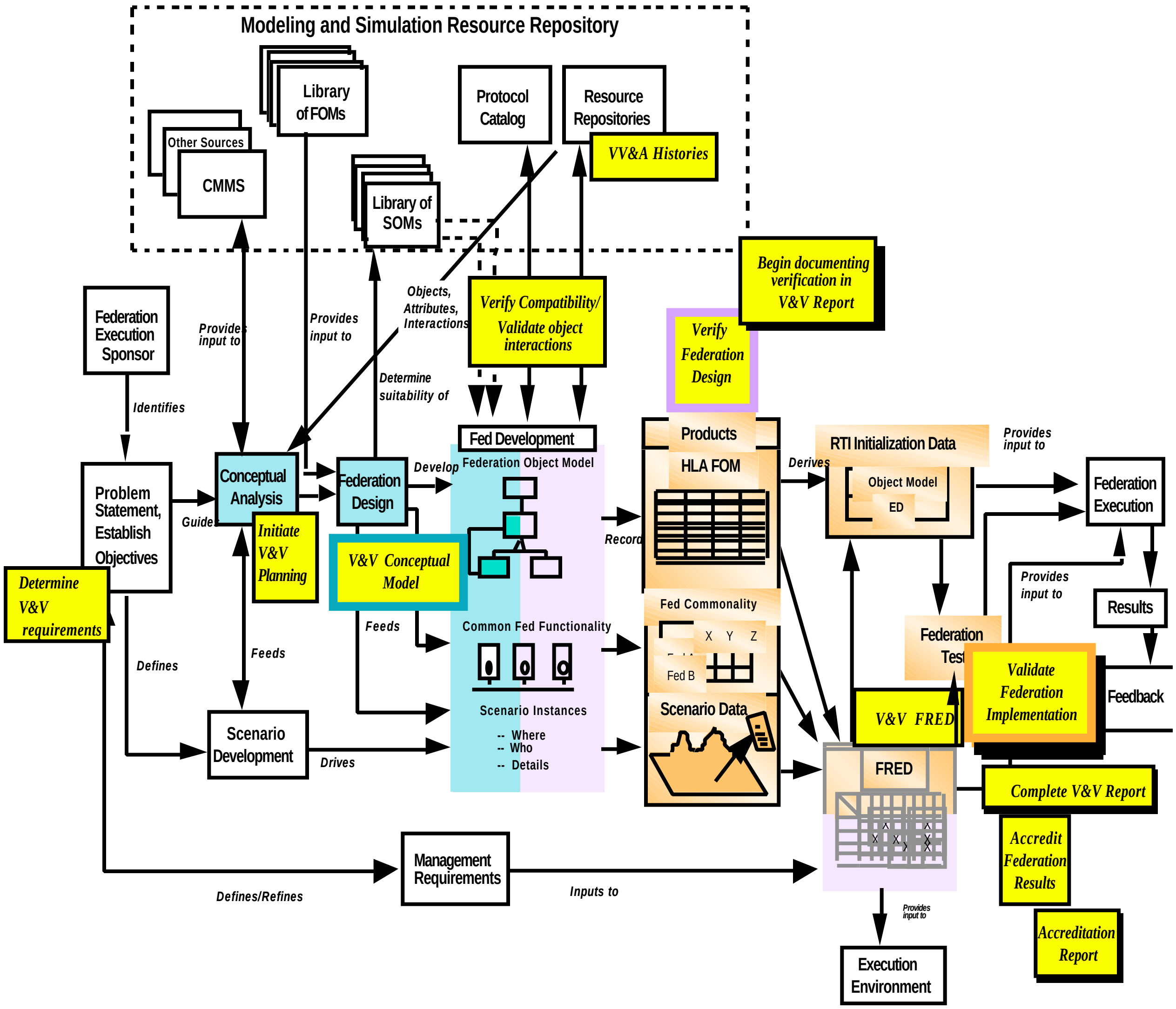



**Figure 3-8. The VV&A Process in the HLA Federation Development Life Cycle**

Another objective of Federation Design is to identify potential opportunities for reuse of existing FOMs and SOMs. As discussed in Section 3.3.2.3, FOMs and SOMs describe the capabilities of federations and federates to assist other users in determining their suitability for new applications. Both *FOMs and SOMs need to be validated against the federations and simulations they represent* to ensure consistency in the descriptions provided with the actual federation or federate.

The Federation Development stage is the final area where V&V of the Conceptual Model occurs. Federation Development bridges the V&V function across the Conceptual Model to V&V of the Federation Design (striped overlay). Conceptual and design activities include FOM development, as well as identification of common functionalities, data requirements, object relationships, common syntax, and semantics. As design features become more detailed, V&V is performed to ensure that they accurately reflect the intent of the conceptual design. MSRR resources also are retrieved during Federation Development. These resources include histories of previous VV&A efforts on federates and federations that are similar in application or that may be considered for application or modification in the current federation. Information from the MSRR is verified to ensure compatibility and to validate object interactions across federates.

Design V&V extends from the Federation Development stage to include part of the FRED. The FRED describes the way the FOM works internally to the federation. Network requirements, physical connections, and delineation of platforms and nodes must all be verified against the developer's specifications. HLA compliance testing meets much of this V&V requirement.

V&V of the implementation of the federation involves the products of the federation development process, portions of FRED, the RTI initialization data, and the federation test (orange/shaded overlay). Federation documents generated during development offer excellent traceability for V&V activities. RTI initialization data show the physical implementation of the rules, interface specifications, and object model. These data, as well as those obtained from FRED, serve as valuable conduits through which V&V is performed to ensure that the implementation of the federation accurately reflects the intended design.

Federation Testing includes both HLA compliance testing and federation functional testing. The former ensures that, when the federation is connected to the RTI, the interface specifications are handled properly and information is passed correctly. This correlates directly to verification, which checks the implementation against the developer's conceptual description and specifications. A similar parallel can be drawn between functional testing, which looks for logical interactions and ensures that the information that is passed makes sense, and validation, which tests the credibility of the implementation against the real world.

Figure 3-8 also indicates the points in the process at which reports and documentation of the VV&A effort should occur. These documents are an integral part of the overall application of M&S.

## 3.4.4 Migration of the Generic VV&A Process to Different Types of Applications

### *3.4.4.1 Legacy M&S*

Figure 3-9 illustrates the generic VV&A process modified to include the two options of using an existing model as is or modifying it to meet new user requirements.

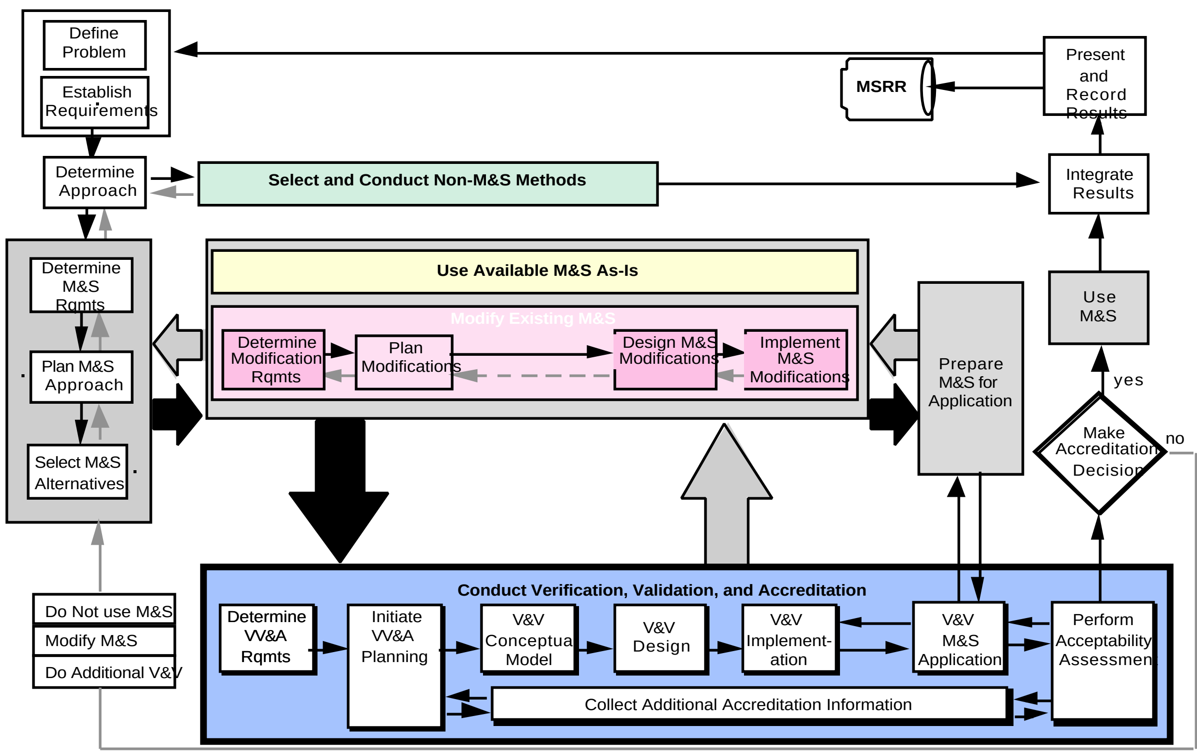



**Figure 3-9. The VV&A Process in the Legacy M&S Life Cycle**

### *3.4.4.2 New M&S*

Figure 3-10 again alters the generic VV&A process to include only those sections pertinent to new M&S development.

### *3.4.4.3 Distributed Interactive Simulation*

The DIS nine-step VV&A process (see Figure 3-11) was accepted by a consensus agreement of the DIS VV&A Subgroup of the DIS Workshop, which represents the training functional area community for distributed simulation. It is discussed in detail in the DIS Recommended Practices Documents being developed for DIS VV&A and DIS Exercise Control. The VV&A process parallels the DIS exercise development process. A major assumption of the DIS process is that each individual component has undergone some level of VV&A (e.g., according to a given Service's policy) independent of a DIS exercise configuration. Each of the nine steps is defined in the following paragraphs.

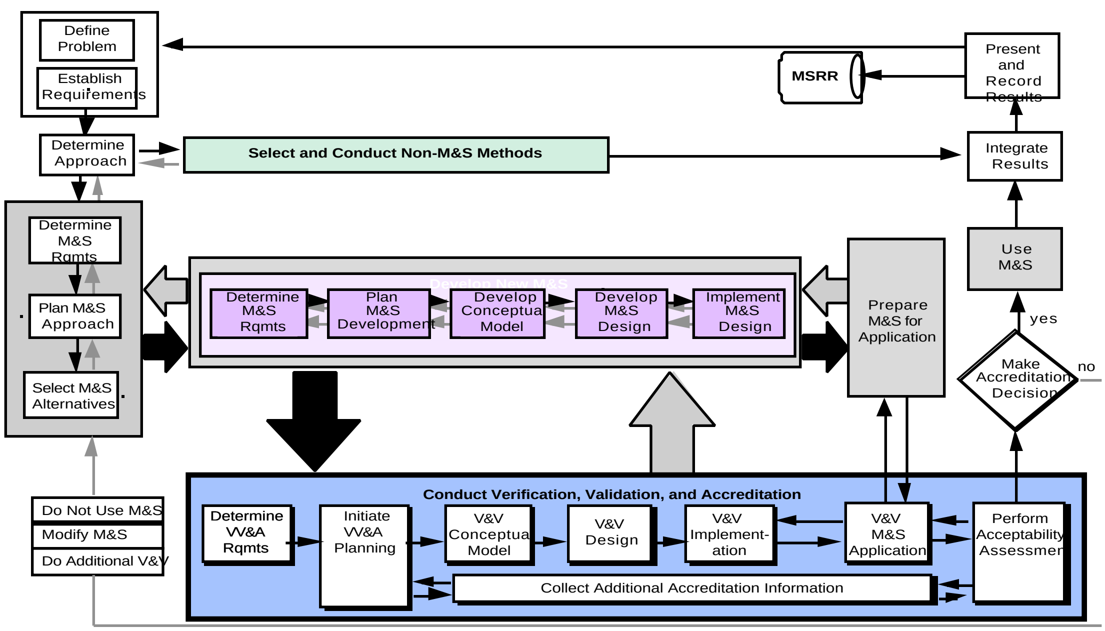



**Figure 3-10. The VV&A Process in the New M&S Life Cycle**

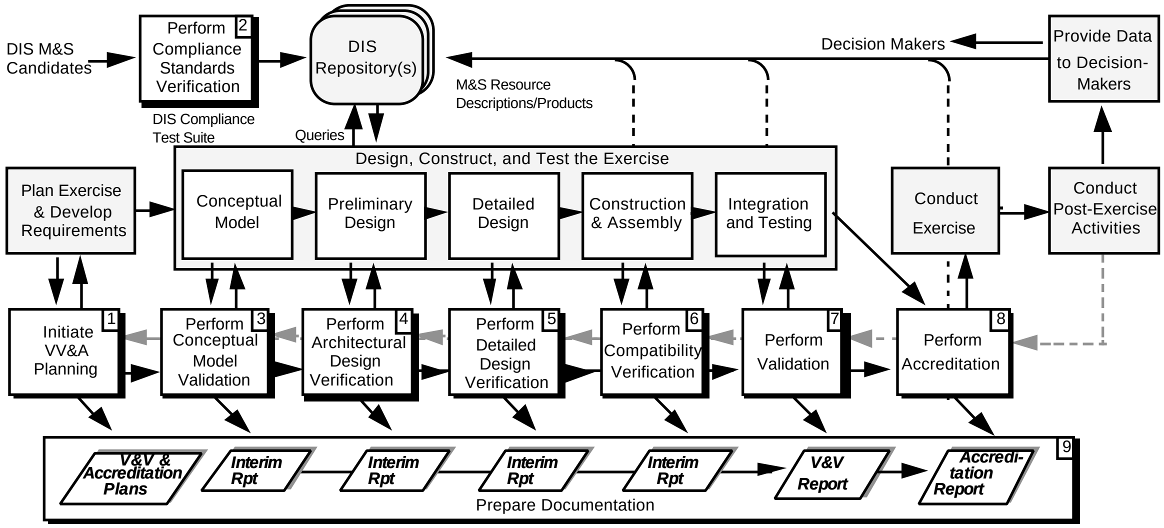



**Figure 3-11. The VV&A Process in the DIS Exercise Management and Feedback Life Cycle**

***3.4.4.3.1 Develop VV&A Plans.*** VV&A planning begins in the earliest stages of DIS exercise development when exercise plans are being produced and the associated exercise requirements, e.g., the type of systems that need to be represented, the level of fidelity that is required, are being defined. At this point, the VV&A and testing plans are conceptualized and drafted, and the exercise requirements are validated.

***3.4.4.3.2 Verify Standards.*** At this stage, proposed DIS components (i.e., model, simulation, or simulator; live, virtual, or constructive) are tested to verify that they can communicate adequately using the DIS Protocol Data Units (PDU). This step can occur before or during DIS exercise development. The Institute for Simulation in Training (IST) in association with the Simulation, Training, and Instrumentation Command (STRICOM) have developed a compliance test suite to assist in testing for protocol compliance.

***3.4.4.3.3 Perform Conceptual Model Validation.*** During this phase, the conceptual model is validated against the exercise requirements. The conceptual model offers an initial configuration of DIS compatible components that satisfies the exercise requirements. Traceability of requirements to the conceptual model and preliminary design is stressed. This step is iterated until a conceptual model that satisfactorily meets the required objectives is defined.

***3.4.4.3.4 Perform Architectural Design Verification.*** This phase of VV&A is tied to the development of the preliminary design or conceptual model for the exercise. Information contained in a DIS repository about candidate DIS components, their associated component level VV&A history, and fidelity characteristics can assist in making design decisions. The conceptual model or preliminary design is verified for correctness and completeness.

***3.4.4.3.5 Perform Detailed Design Validation.*** In the detailed design phase, the preliminary design or conceptual model discussed in Steps 3 and 4 is expanded to a detailed level. Validation at this stage ensures that detailed design is correct and complete and maintains traceability to the requirements.

***3.4.4.3.6 Perform Compatibility Verification.*** At this point, the compatibility of the components within the DIS exercise configuration is verified.

***3.4.4.3.7 Perform Exercise Validation.*** This phase of the V&V process examines how well the DIS exercise configuration represents the behavior, appearance, performance, fidelity constraints, and interoperability levels of the intended application.

***3.4.4.3.8 Perform Accreditation.*** The V&V conducted for the exercise is reviewed by the accrediting authority (i.e., exercise user or sponsor) and an accreditation decision for formal acceptance is made.

***3.4.4.3.9 Prepare VV&A Reports.*** Descriptions and results of the VV&A effort are documented and funneled to the DIS Repository as evidence of VV&A activity and for potential use in future DIS exercises.

As with the HLA development and VV&A processes, the DIS exercise development is directly mapped to the nine-step VV&A process and those processes defined in the generic life cycle and VV&A descriptions of Sections 3.2 and 3.4.

#### *3.4.4.4 Aggregate-Level Simulation Protocol*

VV&A activities are integrated into the development cycle for each year’s confederation and apply only to the ALSP protocols and software. (See Figure 3-12.) The activities focus on ensuring interoperability of component simulations within the confederation framework and on run time performance. Each simulation in the JTC has been approved by a participating Service or Agency and is considered accredited for use in the JTC.

Improvements to the participating simulations, however, are coordinated with the Services and the ALSP office to ensure continued compatibility for future JTCs.

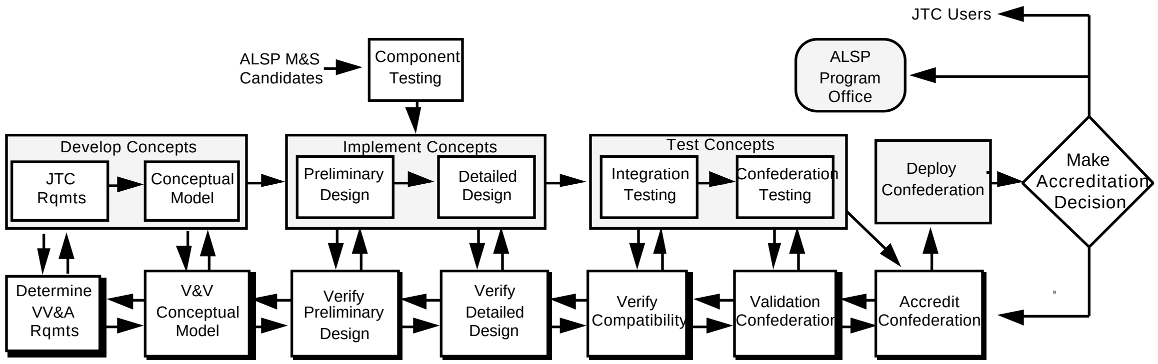



**Figure 3-12. The VV&A Process in the ALSP Life Cycle**

The V&V activities include reviews of each design and document by the ALSP Review Panel. Methods range from formal structured walkthroughs to informal briefings with the level of formality commensurate with the priority or novelty of the concept and the estimated risk associated with its integration.